Subjective Evaluation of Transmission Delay in Telephone Conversations

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An earlier experiment by Riesz and Klemmer on the effect of pure-transmission delay upon natural telephone conversations was extended in a test with more than double the time period and number of calls. The previous finding of little or no adverse reaction to round-trip pure delays of 600 and 1200 msec alone was confirmed. The previous finding of a large increase in dissatisfaction with both of these delays following exposure to 2400 msec was not obtained. Exposure to delays of 2400 msec led to no dissatisfaction with later calls at 600 msec, but some rejections at 1200 msec did occur. There is no contradiction of other results on normal telephone circuits with 2-wire terminations (and related echo sources, paths, and suppressors) wherein customer dissatisfaction is greater with 600 msec delay than with the much shorter delay of a normal long-distance circuit.

A previous paper by Riesz and Klemmer[1] in tbis journal described laboratory experiments on the effect of transmission delay upon the quality of telephone circuits for normal conversation. These experiments were of two types: (*i*) "pure delay" tests in whicb long transmission times were employed, but the side effects of echo and echo suppressors were avoided by using special 4-wire telephone circuits and (*ii*) "2-wire" tests which used long transmission times in normal 2-wire circuits (or circuits with 2-wire terminations) with echo sources and echo suppressors.

Since the publication of these experiments, several evaluations outside the laboratory have been done on circuits witb long transmission times and naturally-occurring telephone calls (e.g., Helder,[2] Klemmer[3]). These studies have borne out the earlier laboratory finding of considerable dissatisfaction with 2-wire circuits for round-trip delays of 600 msec or more. The pure delay condition could not be evaluated in the field tests since it requires complete separation of the transmitting and receiving paths which is not available in tbe normal telephone

plant.* Even though the pure delay condition is not obtainable in the telephone network used by the public for domestic and overseas calls, it is of interest because it represents a limiting point for the effect of transmission delay on the quality of the circuits for conversation. It is not likely that any changes in echo suppressors or other circuit devices would produce better transmission quality than a 4-wire system with the same transmission time. Thus, if the degradation noted in the natural 2-wire circuits with long delay were present in similar amount on 4-wire circuits of the same delay, there would be little hope of improving transmission quality by improving echo control methods. If, on the other hand, the effects of pure delay alone are much less than that due to delays, echo, and echo suppression, then improvement in echo control methods is definitely indicated.

The results of the previous laboratory study with pure delay were very limited in number of people and calls, and also confounded by the introduction of extremely long delays (2400 msec) in the middle of the experiment. The data had shown little or no dissatisfaction with pure delays of 600 and 1200 msec prior to the introduction of the 2400-msec delay, but showed an increasing rejection of circuits with the lesser delays after exposure to the 2400-msec condition.

The chief purpose of the present experiment was to see if an increasing rejection rate would occur with continued exposure to pure delays of 600 and 1200 msec only. Therefore, the present experiment repeats the 12 weeks of the previous pure delay study but without the introduction of the 2400-msec delay.

After the 12 weeks of alternate days of 600- and 1200-msec delay, periods of 1800- and 2400-msec delay were inserted to re-evaluate the effect that these longer delays would have upon the users reaction to following days of 600- and 1200-msec delay.

I. SIMULATION APPARATUS: SIBYL

The simulator called Sibyl, which permits the insertion of experimental circuits into naturally-occurring telephone calls, was the same as that employed in the previous study[1] and is described by Irwin.[7] Elimination of echo and echo suppressors is attained by converting all telephone instruments to full 4-wire operation, separating the transmit and receive paths. Normal sidetone was provided within each telephone set.

*Other laboratory tests on the effect of pure delay upon conversational tasks have been reported by Bricker,[4] Krauss and Bricker,[5] and Vartabedian.[6] These did not involve naturally-occurring telephone calls, and thus, are not directly comparable to the tests described here.

II. SUBJECTS

Twenty administrative employees of Bell Telephone Laboratories were selected on the basis of questionnaires sent to several hundred people asking about frequencies of telepbone calls to other extensions in Bell Laboratories. Tbese people were selected to form a group witb a high reported-rate of calling each other since the delay circuits could only be used when they called each other.

III. INSTRUCTIONS

The participants were told that some of their calls would go over special experimental circuits. They were not told which calls would be affected or anything about the nature of the experimental circuits. They were told that if they found any circuit "unsatisfactory for normal telephoning" they should dial the digit "4" without hanging up or breaking the connection, and the standard circuit would be restored. The instructions called for the originating party to reject the circuit, but actually either party could reject the experimental circuit and the few instances of rejection by the called party were also counted as rejected calls.

IV. EXPERIMENTAL DESIGN

The schedule of delays on the experimental circuits was as follows:

Weeks 1 through 12	600 and 1200 msec on alternate days
Weeks 13 through 14	1800 msec every day
Weeks 15 through 16	2400 msec every day
Weeks 17 through 26	600 and 1200 msec on alternate days.

The delay for the day was inserted on each call made by one subject to another subject unless the simulator was already in use. No calls involving other stations could be put over the experimental circuits (because of the 4-wire requirement), and therefore, only a small percentage of any subject's calls went over the experimental circuits. The subjects were not told of this limitation and none reported knowledge of it in the post-test interviews.

V. RESULTS

The percentage of calls rejected for each two-week period of the experiment is plotted in Fig. 1 for each delay separately for the first

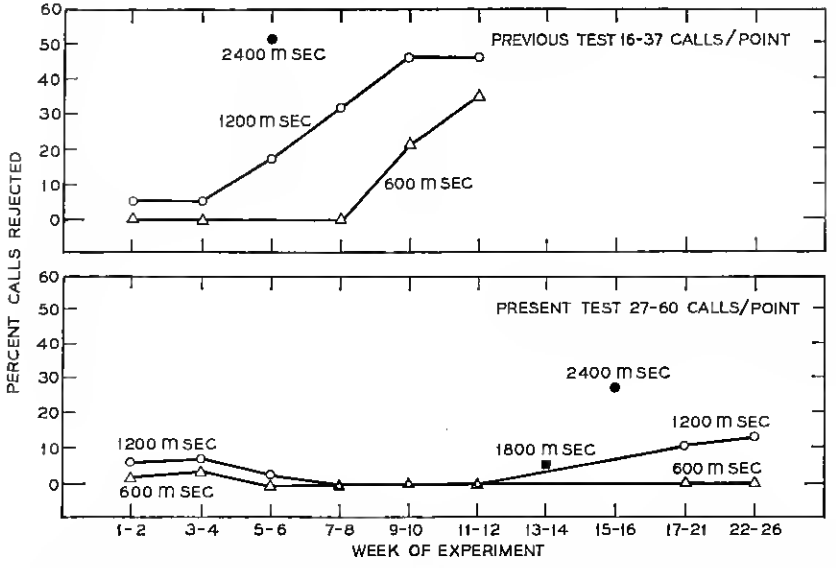

Fig. 1 — Rate of rejection of circuits as a function of weeks of the experiment from Riesz and Klemmer[6] and for the present experiment. Combined data from 18 and 20 subjects, respectively.

12 weeks of the test. The data from the previous study[1] is also shown. Clearly, the rising rejection rate of the previous study was not found, indeed, there were no rejections at either 600 or 1200 msec for weeks 7 through 12. In the first 12 weeks of the present study, a total of 527 calls were made over the delay circuits. This compares with 323 calls made during the entire earlier study. Thus, it is clear that increasing rejection of pure delays of 600 and 1200 msec is not to he expected from repeated exposures to these delays only.

The results during and after the longer delays in the experiment are also shown in Fig. 1. Two weeks at 1800 msec resulted in 5 percent rejections (3 calls of 60). Two weeks at 2400 msec resulted in 27 percent rejections (14 calls of 52). Six different people rejected calls at 2400 msec. Eighteen of the 20 subjects talked over the 2400-msec delay, and these 18 people made 97 percent of the calls over experimental circuits during the final 10 weeks when 600- and 1200-msec delays were again used on alternate days. Thus, the data following 2400-msec delay comes almost entirely from people who had been exposed to 2400 msec.

Because of vacations and illnesses there are not enough data during the final 10 weeks to plot biweekly points. Samples of comparable size to the first 12 weeks are obtainable by using two 5-week periods and these points are shown in Fig. 1. No additional rejections of the 600-msec circuit occurred during this period. Thus, there was no "sensitization" to that delay. The 1200-msec condition led to 12 percent rejection (7 of 57 calls) following exposure to long delays. (Note that in Fig. 1 the small difference in percentages between the two final periods at 1200 msec is not statistically meaningful.) The occurrence of some rejections at 1200 msec following exposure to the longer delays indicates some sensitization since 1200 msec had zero rejections from 6 weeks (94 calls) prior to the long delays.

Telephone interviews were conducted with the 16 subjects who were available at the end of the test. They were asked if they, or the people with whom they talked, had difficulty in talking or hearing on calls within the PBX during the time of the test, or if they noticed anything different about any calls. Eight (half) of the respondents said they had no difficulty and noticed nothing different about their calls. Eight reported difficulties due to: low volume (2); slow answer (2); fading (1); fuzziness (1); noise (1); and another party could not hear (1). One person, in addition, reported hearing echo (perhaps due to an air path feedback between receiver and transmitter). Of those who reported difficulty, one rated the condition not objectionable, two mildly objectionable, one moderately objectionable, and three seriously objectionable. One of those reporting seriously objectionable difficulty had never rejected a delay call, but several times dialed "4" on normal calls. He said the trouble was loss and dialing "4" did not help.

The interview data cannot be taken as a reliable measure of the circuit quality for three reasons: (*i*) The questions related to a large population of calls, only a few of which were actually over the delay circuits, (*ii*) The test lasted several months, and the subjects could hardly be expected to sort out accurately and remember all individual calls, and (*iii*) The subjects reported difficulties and attempted rejections on normal calls not involving the delay circuit at all. The interviews do, however, show that most of the time the participants were not aware that there was anything different about their connections when delays of 600 or 1200 msec were inserted. Indeed, eight people reported that they noticed nothing different about their circuits even though this group had actually talked on a total of 85 calls with 1800- or 2400-msec delay and many more calls at the smaller delays.

VI. DISCUSSION AND CONCLUSIONS

The first 12 weeks of the present study repeated the procedure of the previous pure delay tests except that the intermediate exposure to 2400 msec was omitted. Under these conditions of exposure to only 600 and 1200 msec, no increased dissatisfaction with delay circuits developed even though a much larger number of delay calls were made in the new study. This result alone obviously implies that exposure to the 2400-msec delay was responsible for the later rejections of the 600- and 1200-msec conditions in the previous study. The results of the later weeks of the present study provide limited support for this hypothesis, however. After exposure to 1800- and 2400-msec delay, *no* rejections of the 600-msec condition occurred but 12 percent of the 1200-msec calls were rejected. In the previous study, after exposure to 2400-msec delay, the 600-msec condition was rejected in 25 percent of the calls, and the 1200-msec condition was rejected in 43 percent of the calls.

In view of the differences in results between the two studies regarding the influence of exposure to 2400-msec delay, it might be best to withhold judgment about the magnitude of the sensitization effect. There is no disagreement, however, on the more direct and important question about user's reaction to pure-transmission delays of 600- and 1200-msec round-trip delays when these are not confounded with the longer delays or speech-operated devices. Users are very seldom disturbed by these pure delays as is indicated by the fact that during the second 6 weeks of the present study the participants completed more than 200 calls without a single rejection.

This conclusion is supported by the field test results[2, 3] which show for round-trip delays of 600 msec (on 2-wire circuits with echo sources and echo suppressors) that less than 1 percent of the people interviewed immediately after a call over the delay circuit said anything which implies an awareness of the delay itself. This is true despite the fact that 25 percent or more of the respondents report some difficulty in talking or hearing on the 600-msec circuit and only half that many report difficulty on circuits with delays less than 100-msec delay (normal overseas cable circuits).

Although users are not aware of a transmission delay of 600 msec it is clear that the delay must affect the conversational patterns in such a way as to cause other types of difficulty in actual 2-wire circuits, difficulties such as speech mutilation by echo suppressors. In addition, there is evidence that for tasks other than naturally occur-

ring conversation, delays of 600 to 1800 msec may significantly lower performance (Krauss and Bricker,[5] Vartabedian[6]). Studies of speech dynamics under various transmission delays are underway to understand this effect better.

VII. ACKNOWLEDGMENTS

M. A. Pilla was responsible for the Sibyl simulator. A. Y. Kimura conducted the initial survey of potential participants. A. P. Winnicky supervised the data collection.

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